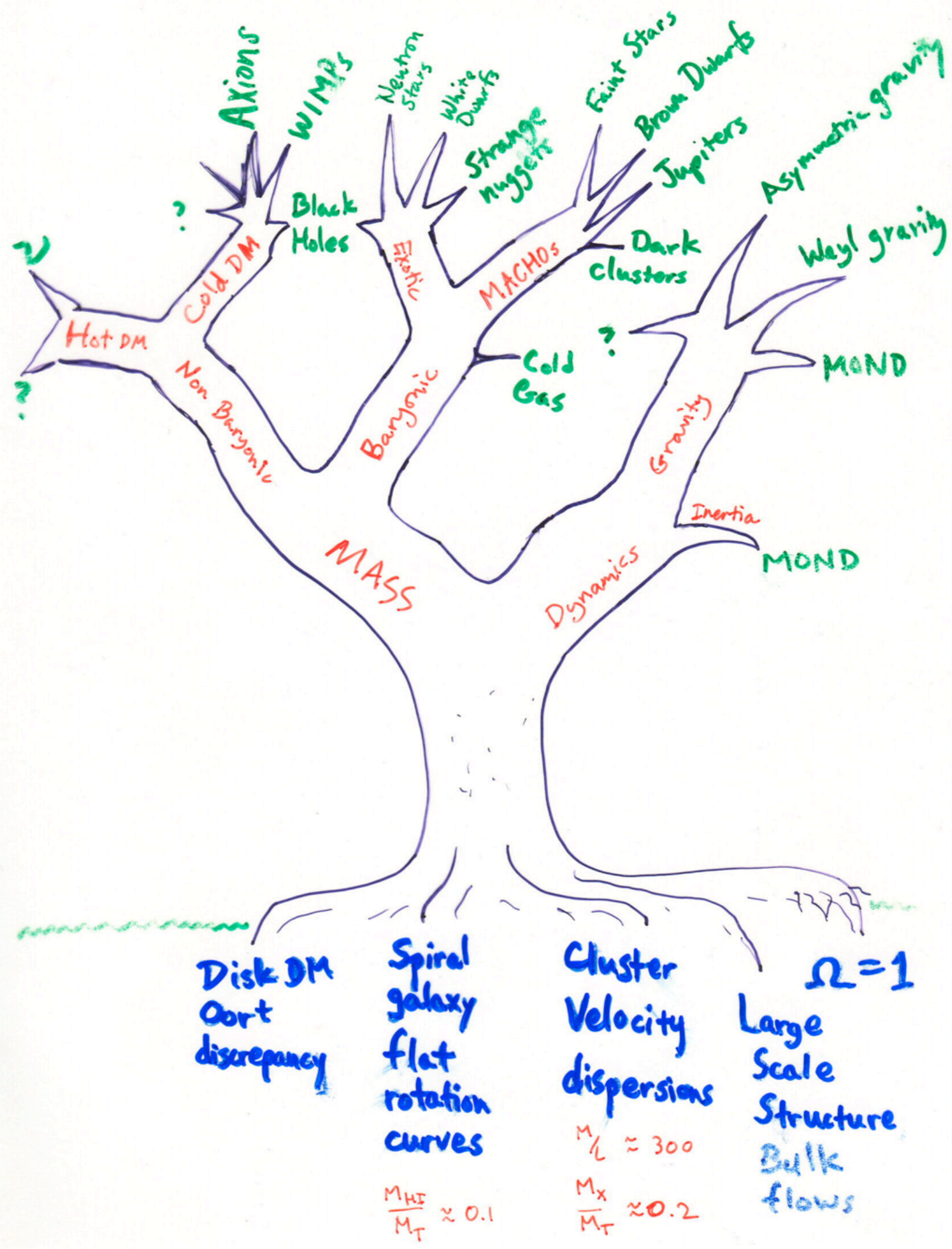


DARK MATTER

ASTR 333/433

TODAY

MONOLITHIC AND HIERARCHICAL GALAXY FORMATION



Galaxy Formation

A many faceted problem

(sort of like Cthulhu being a multi-tentacled nightmare cult god)

Competition between gas accretion (to form disks)
and lumpy fragments (forms spheroids, substructure)



Monolithic galaxy formation collapse of one big gas cloud

(e.g., Eggen, Lynden-Bell, & Sandage 1962)

Hierarchical galaxy formation

“bottom up” formation from sequence of mergers

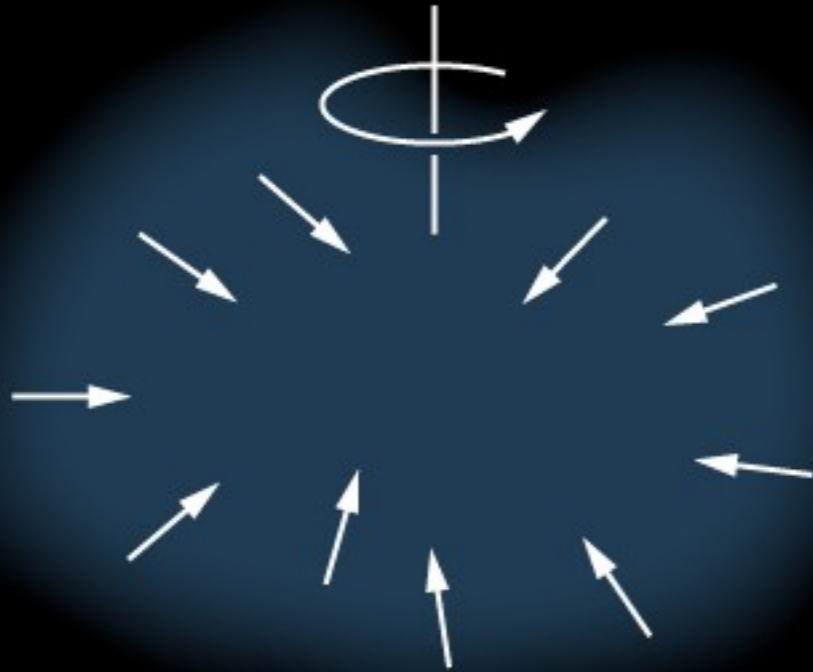
(big galaxies are built up with small galaxies - modern picture with CDM)

Searle-Zinn (1978) fragments:

“...halo [globular] clusters originated within transient protogalactic fragments that gradually lost gas while undergoing chemical evolution and continued to fall into the Galaxy after the collapse of its central regions had been completed.”

Monolithic galaxy formation

1 gas starts to collapse



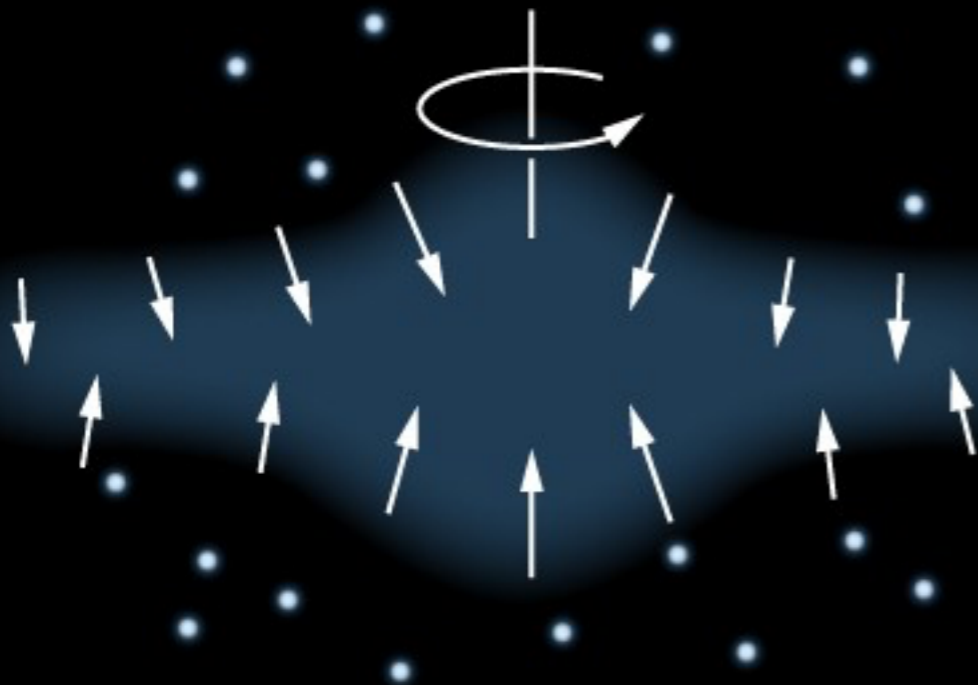
Collapse of a giant cloud of primordial gas

2 first stars form during collapse



retain memory of infall in their radial orbits

3 gas settles into disk



plane of disk specified by initial angular momentum

4 stars form in disk



Good at forming spiral galaxies

Hierarchical galaxy formation

(bottom up - *not* monolithic)

Small objects conglomerate to make big ones

Gas dissipates and cools to form thin disks.

Stars cannot cool: if hot coming in, stay hot.

merger tree

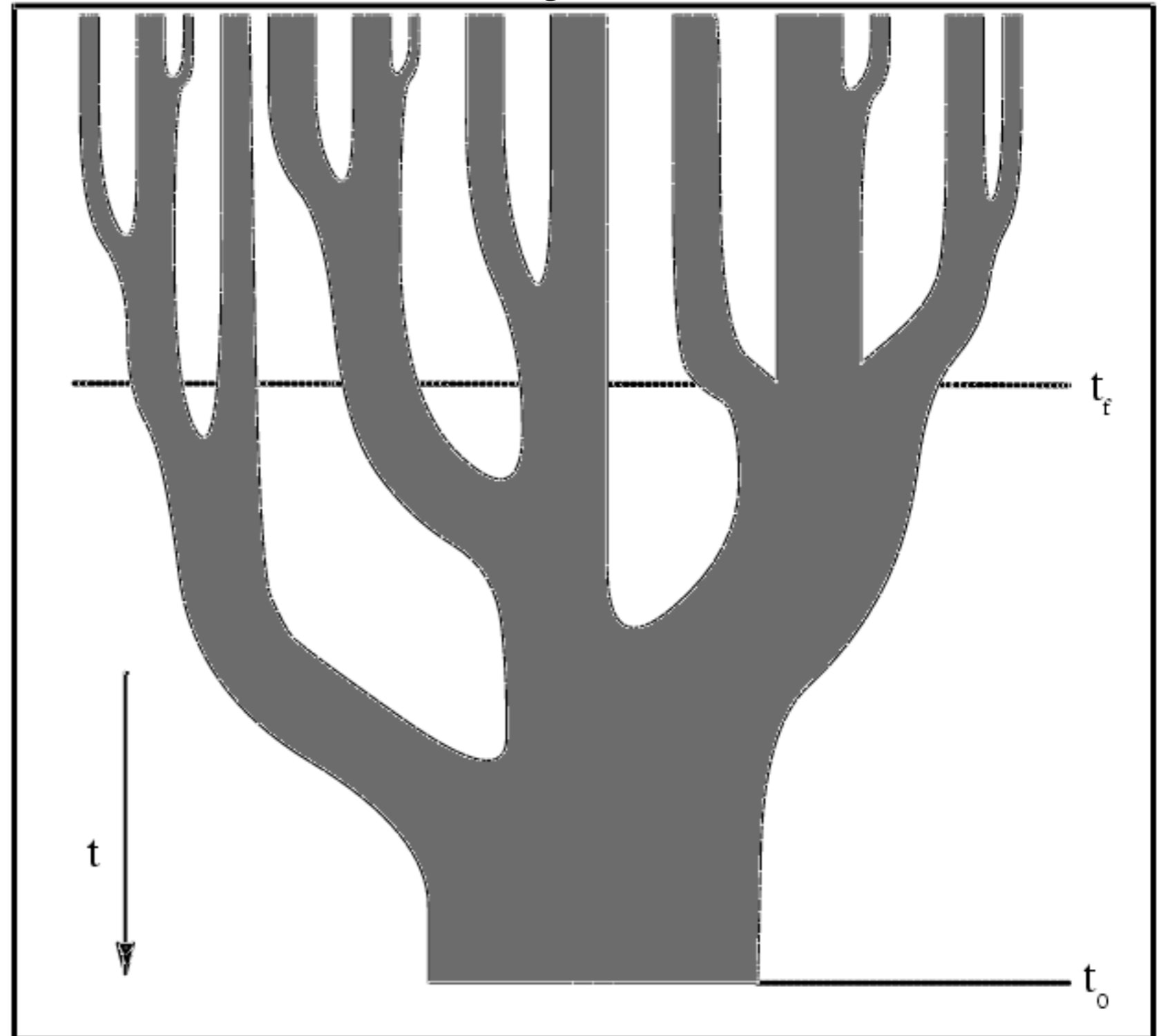


Figure 6. A schematic representation of a “merger tree” depicting the growth of a halo as the result of a series of mergers. Time increases from top to bottom in this figure and the widths of the branches of the tree represent the masses of the individual parent halos. Slicing through the tree horizontally gives the distribution of masses in the parent halos at a given time. The present time t_0 and the formation time t_f are marked by horizontal lines, where the formation time is defined as the time at which a parent halo containing in excess of half of the mass of the final halo was first created.

merging subhalos



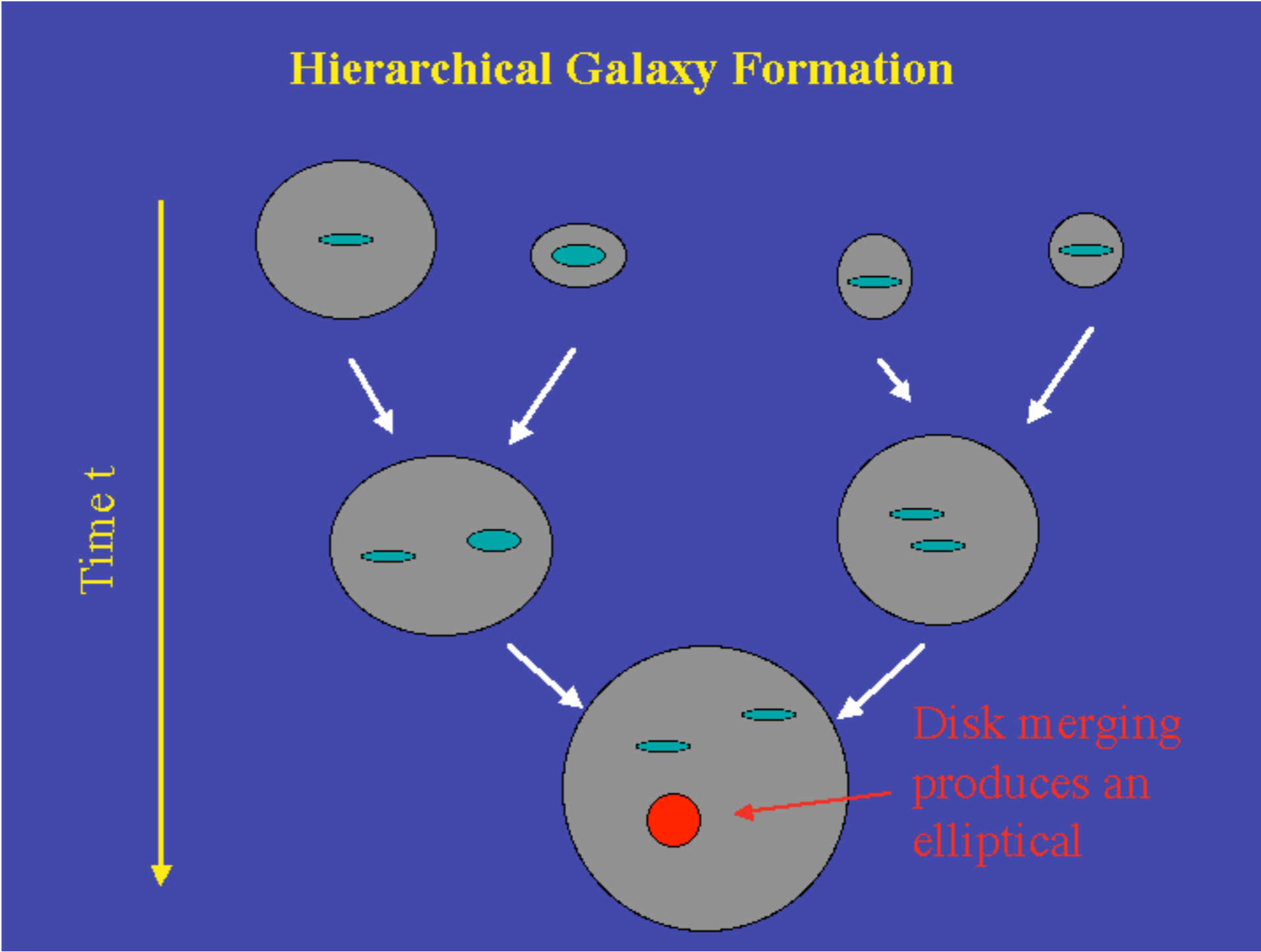
merging subhalos containing protogalaxies

Gray:
dark matter halos

Blue:
gas rich disks

Red:
elliptical merger
remnant

sometimes it is
imagined that a disk
re-forms around an
elliptical to form a
bulge+disk system
like and Sa galaxy



Good at forming elliptical galaxies

Sequence of events in galaxy formation

1. Dark matter halos form; merge into ever larger masses
2. Baryons fall into the potential wells of DM halos
3. Gas dissipates, sinks to centers of DM halos
 - Halos compressed by sinking baryons
 - gas forms rotating disks at centers of DM halos
4. Stars form in disks
 - Feedback heats gas, dissuading further gas accretion
5. Mergers transform some disks into ellipticals
 - star formation truncated
6. Renewed gas accretion may re-form disks around ellipticals
 - thus becoming the bulges of S0s and early type spirals
7. Merging lessens; more gradual accretion of dark matter and gas may continue
8. Galaxies

